# SPECIFICATION

To All Whom It May Concern:

Be It Known That I, Mircea Gradu, a citizen of the United States of America and a resident of the City of Wooster, State of Ohio, whose post office address is 1109 Greensview Drive, Wooster, Ohio 44691 have invented certain new and useful improvements in

**STABILIZER BAR HAVING VARIABLE TORSIONAL STIFFNESS**

## CROSS REFERENCE TO RELATED APPLICATIONS

Not applicable.

## STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Not Applicable.

## BACKGROUND OF THE INVENTION

This invention relates to suspension systems for automotive vehicles and more particularly to a stabilizer bar for a suspension system.

The typical passenger automobile has independently suspended front wheels, as do similar vehicles, such as sports utility vehicles, vans, and light trucks. In order to prevent excessive body roll in such vehicles when they negotiate turns, particularly at higher speeds, the vehicles are equipped with stabilizer bars that connect the sides of their front suspensions. Each side on such a vehicle includes at least one control arm and a steering knuckle to which a wheel end is attached, with one of the front wheels being mounted on the wheel end. The stabilizer bar constitutes nothing more than a torsion bar that extends transversely across the front of the vehicle where it is attached to the frame or body of the vehicle, yet is free to rotate. At its ends, the stabilizer bar has torque arms which are attached to the control arms. As a consequence, the control arms tend to move in unison in the same direction and transfer forces to the frame – forces which modulate and retard roll.

While a stabilizer bar will improve the control and orientation of a vehicle when the vehicle negotiates a turn, particularly at high speeds on paved

surfaces, it detracts from the ride when the vehicle travels along straight road surfaces. Moreover, it makes travel at low speeds, either straight or through turns, more uncomfortable than it could otherwise be. After all, when one wheel is deflected upwardly, such as by encountering a bump, the other wheel will attempt to lift as well, since the stabilizer bar connects the control arms for both wheels, and oppositely directed forces are applied to the vehicle frame. This can produce a rocking motion when the vehicle travels off road or over uneven road surfaces – a phenomenon sometimes referred to as "antiroll bar waddle". Hence, different driving conditions call for stabilizer bars with different torsional stiffness. At one extreme are the conditions encountered off road and on secondary roads traveled at relatively low speeds and also those encountered on straight segments of paved roads. These conditions require low torsional stiffness. At the other extreme are the conditions encountered when negotiating turns on paved surfaces at high speeds. These conditions require high stiffness. Most stabilizer bars have high stiffness to resist roll and maintain control in turns.

## BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

Figure 1 is a perspective view of a suspension system provided with the stabilizer bar of the present invention;

Figure 2 is a longitudinal elevational view, partially broken away and in section of the coupling and valve for the stabilizer bar;

Figure 3 is a sectional view taken along line 3-3 of Fig. 2; and

Figure 4 is a fragmentary sectional view taken along line 4-4 of Fig. 3.

Corresponding reference characters indicate corresponding parts throughout the several views of the drawings.

## DETAILED DESCRIPTION OF INVENTION

Referring now to the drawings, an automotive vehicle has a suspension system A (Fig. 1) that is attached to a rigid structural component B, such as a frame or a unified body, of the vehicle. The suspension system A couples left and right road wheels C to the structural component B such that the road wheels C can displace vertically with respect to the structural component B. The suspension system A includes a stabilizer bar D which is attached to both sides of the structural component B and, in effect connects the left and right wheels C. The arrangement is such that when the body of the vehicle rolls – and with it the structural member B – the stabilizer bar D, being extended between the two wheels C, resists the tendency to roll, assuming of course, that it possesses a good measure of torsional stiffness. But when one of the wheels C is displaced vertically, the bar D may transmit a force to the opposite wheel C and that force will urge the opposite wheel C in the same direction as the displacement if the bar D possesses the same torsional stiffness. Actually, the torsional stiffness of the bar D can be varied to accommodate differing road and driving conditions.

Considering the suspension system A in more detail, it may be a double wishbone or McPherson strut suspension. Either one, on each side of the vehicle, includes (Fig. 1) control arm 2 that is attached to the structural component B such that it can pivot about an axis that extends generally

longitudinally with respect to the vehicle. The control arm 2 extends laterally from that pivot axis, and at its outboard end is fitted with suspension upright 4, the two being coupled together such that they can pivot relative to each other. When the suspension upright 4 steers the vehicle, it takes the form of a steering knuckle that is coupled to the control arm 2 through a universal pivot, such as a ball-and-socket joint. In any event, the suspension upright 4 supports a wheel end 6 to which one of the road wheel C is attached. The typical wheel end 6 has a housing that is attached to the upright 4, a hub to which the road wheel C is secured, and a bearing between the hub and housing to enable the hub and wheel C to rotate on the suspension upright 4 with minimal friction. Finally the suspension system A at each side of the vehicle, has a spring 8 or torsion bar which is extended between the control arm 2 and the structural component B to support the vehicle on the wheel C toward which the control arm 2 extends.

The stabilizer bar D includes (Fig. 1) left and right sections 16 and 18 and a coupling 20 located between the sections 16 and 18, and also a valve 22 connected to the coupling 20. Each section 16 and 18, in turn, includes a torsion rod 24 and a torque arm 26. The torsion rods 24 extend transversely on the vehicle and lie along a common transverse axis X. Each is encircled by a bushing 28 over which a clamping bracket 30 fits. The brackets 30 are, in turn, attached firmly to the structural component B to thus secure the stabilizer bar D to .the component B. Even so, the torsion rods 24 can rotate within their respective bushings 28. The torque arms 26 extend from the outboard ends of the torsion rods 24 at a substantial angle with respect to the axis X and lie

generally longitudinally in the vehicle. At their ends remote from the torsion rods 24 they are connected to the control arms 2 through vertical links 32 – the torque arm 26 of the left section 16 being connected to the left control arm 2 through one link 32 and the torque arm 26 of the right section 16 being connected to the right control arm 2 through another link 32.

The coupling 20 together with the valve 22 controls the torsional stiffness of the stabilizer bar D. Whereas the coupling 20 is located between the left section 16 and the right section 18, the valve 22 may be located remote from those sections 16 and 18, perhaps on the structural component B. The two are connected through a flexible fluid line 34.

Considering the coupling 20 first, it has several coupling members including (Fig. 2) a housing 36, , a rotor 38 which rotates relative to the housing 36, and a piston 40 which is also located within the housing 36 where it moves axially, but not rotationally, with respect to the housing 36. In addition, the coupling 20 has rolling elements in the form of generally cylindrical rollers 42 located between the rotor 38 and the piston 40. The housing 36 is attached rigidly to the left section 16 at the end remote from the link 31 for that section, while the rotor 38 is attached rigidly to the right section 18. Thus, the coupling 20 resides between the two clamping brackets 30 where the stabilizer bar D is attached to the structural component B. The coupling 20 enables the two sections 16 and 18 to rotate relative to each other, although through an arc of generally no more than about 20°, and also is capable of locking the two sections 16 and 18 together.

The housing 36 includes (Fig. 2) an end wall 46, which is attached firmly to the torsion rod 24 of the left section 16, and an axial wall 48, which extends from end wall 46 and encloses both the rotor 38 and piston 40. The end wall 46 contains a splined socket 50 which has its center along the axis X and opens into the volume enclosed by the axial wall 48. The axial wall 48 has a smooth interior surface 52 of cylindrical shape, its center also being along the axis X. The housing 36 also includes an end cap 54 which is attached firmly to the axial wall 48 at the end opposite from the end wall 46.

The rotor 38 is joined rigidly to the torsion rod 24 of the right section 18 and fits within the housing 36 where it may rotate in a limited arc immediately behind the end cap 54. The torsion rod 24 for the right section 18 fits within a bearing 60 carried by the end cap 54 to enable that rod 24 and the rotor 38 to rotate in the housing 36. The rotor 38 has a back face 62 which bears against the inside face of the end cap 54 to thereby fix the axial position of the rotor 38 within the housing 36. At its opposite end the rotor 38 has a front face 64 provided with ramps 66 which are arranged in pairs (Figs. 3 & 4), with the ramps 66 of each pair descending into a valley 68 located between those ramps 66. The pairs of ramps 66 and the valleys 68 between them are arranged at equal circumferential intervals around the axis X.

The piston 40 likewise fits within the housing 36 and is provided with (Fig. 2) a splined stub shaft 70 which projects into the splined socket 50 of the housing 36. Indeed, the spline on the stub shaft 70 engages the spline of the socket 50 so that the piston 40 cannot rotate in the housing 36, yet can shift axially in it. Along its periphery the piston 40 has a seal 72, such as an elastomeric O-ring, which wipes

the cylindrical interior surface 52 on the axial wall 48 of the housing 36 as the piston 40 shifts axially to and fro in the housing 36. The piston 40 has a front face 74 which is presented toward the front face 64 of the rotor 38, and like the rotor front face 64, it has (Figs. 3 & 4) ramps 76 arranged in pairs, with the ramps 76 of each pair descending into a valley 78. In number the pairs of ramps 76 and valleys 78 equal their counterparts in the face 64 of the rotor 38. Moreover, the circumferential spacing is the same. When the valleys 78 of the piston 40 align with the valleys 68 of the rotor 38, the torsion arms 26 for the two sections lie at the same angle with respect to the coupling 20. The piston 40 also has a back face 78 which is presented toward, yet is spaced from, the end wall 46 of the housing 36, thus forming a cavity 80 in the housing 36. The cavity 80 contains a magneto-rheological fluid 82 which further fills the flexible line 34 and the valve 22. The end wall 46 of the housing 36 is fitted with a port 84 opens into the cavity 80, and the flexible fluid line 34 connects to the coupling 20 at the port 84.

The rollers 42 of the coupling 20 reside between the ramps 66 on the rotor 38 and the ramps 76 on the piston 40 (Figs. 2 & 4), there being a single roller 42 between each pair of ramps 66 on the rotor 38 and the corresponding ramps 76 on the piston 40. When the piston 40 is farthest from the end wall 46 of the housing 36 and the cavity 80 has its greatest volume, the rollers 42 lie in a centered position (Figs. 2-4) within the valleys 68 and 78. However, when the rotor 38 rotates, the rollers 42 roll along the ramps 66 and 76 on the rotor 38 and piston 40, respectively. This forces the piston 40 away from the rotor 38 and decreases the size of the cavity 80. Movement in the opposite direction of rotation back to the centered position

allows the cavity 80 to expand back to its maximum volume. Of course, rotation in either direction away from the centered position causes the cavity 80 to decrease in volume which results in a displacement of fluid 82 from the cavity 80. It flows outwardly into the line 34.

The valve 22, which is located remote from the coupling 20, has (Fig. 2) a housing 90 including a cylindrical wall 92 and end walls 94 and 96 at the ends of the cylindrical wall 92, there being fluid-tight seals between the end walls 94 and 96 and the cylindrical wall 92. In addition, the valve 22 has a restrictor 98 located within its housing 90 between the two end walls 94 and 96, it being supported there in a fixed position by a support rod 100 which extends from the wall 94. The restrictor 98 has a cylindrical peripheral surface 102 which is set slightly inwardly from the interior surface of the cylindrical wall 92 on the housing 90, so that an annular gap exists between the restrictor 98 and the housing 90. The restrictor 98 contains an electrical coil 104 which, when energized, produces a magnetic flux that passes through the housing 90.

The end wall 96 carries a flexible diaphragm 106 which lies between it and the restrictor 98. The diaphragm 106 divides the interior of the housing 90 into two chambers – one a small accumulator chamber 108 and the other a larger rheological chamber 110. The accumulator chamber 108 contains a pressurized gas, such as nitrogen. The larger rheological chamber 110, which is occupied in part by the restrictor 98, contains the magneto-rheological fluid 82. To this end, the end wall 94 has a port 112 which is connected to the other end of the flexible fluid line 34.

The coil 104 of the valve 22 is connected to a source of electrical energy through a control device which controls the potential impressed across the coil 104 and the current flowing through it. Normally, the magneto-rheological fluid 82 flows quite freely, that is to say, it has a low viscosity. Hence, it will flow through the gap between the cylindrical wall 92 of the valve housing 90 and the peripheral surface 102 of the restrictor 98 with relative ease. However, when the coil 104 is energized it produces a magnetic flux which passes through the large rheological chamber 110 at each end of the restrictor 98 and also through the gap between the restrictor 98 and the cylindrical wall 92 of the valve housing 90. In the presence of the magnetic flux the fluid 82 acquires a greater viscosity and thus flows less freely through the gap – and less freely out of the cavity 80 in the coupling 20 as well.

Under some driving conditions, it is best to have the left and right sections 16 and 18 of the stabilizer bar D operate somewhat independently of each other, so that very little torque transfers between them at the coupling 20. Such conditions require low torsional stiffness in the bar D. On the other hand, other driving condition require a good measure of stiffness in the bar D so that torque exerted on the section 16 transfers to the section 18 or vice versa. The valve 22, and particularly the coil 104 in the valve 22, controls the stiffness of the bar D.

As torque is applied to the stabilizer bar D the rotor 38 seeks to rotate relative to the housing 36 and piston 40. if it does, the rollers, 42 will move out of the valleys 68 and 78 and ride up opposed ramps 66 and 76 on the rotor 38 and piston 40, respectively. This drives the piston 40 away from the rotor 38 and decreases the volume of the cavity 80 in the coupling 20. Some of the magneto-rheological fluid 82

in the cavity 80 is displaced, thus forcing more fluid into the rheological chamber 110 of the valve 22. The diaphragm 106 flexes to accommodate the additional fluid 82. However, in order to displace the diaphragm 106 some of the fluid 92 in the chamber 110 must flow through the gap between the restrictor 100 and the cylindrical wall 92 of the valve housing 90. The ease with which the fluid 82 flows through the gap depends on the viscosity of the fluid 82 in the region of the gap, and that in turn depends on the magnetic flux produced by the coil 104 and, of course, the current flowing through the coil 104. In other words, the stiffness of the bar D depends on the ease with which the fluid 82 is displaced from the chamber 80 of the coupling 20 and that in turn depends on the magnitude of the current in the coil 104 of the valve 22. The latter is easily controlled manually, such as with a rheostat, or by an automatic system which includes sensors that detect the speed of the vehicle, vertical acceleration to determine the condition of the surface over which the vehicle travels and lateral acceleration to determine the severity of the turns negotiated.

When the rotor 38 and piston 40 return to their initial position in which the rollers 42 are centered in the valleys 68 and 78, the cavity 80 enlarges under the pressure exerted on the fluid by the compressed gas in the accumulator chamber 108.

Variations are possible. For example, the restrictor 98 in the valve 22 may contain apertures in lieu of a gap around the periphery or in addition to such a gap. Moreover, the fluid 82 need not be entirely magneto-rheological. On the contrary, only the portion of the fluid in the valve 22 need have magento-rheological properties. In that event, the remaining portion of the fluid 82 could be separated from the

rheological portion with a diaphragm or a piston. Actually, the fluid need not be rheological at all if the valve is constructed to vary and control the rate at which it escapes from the cavity 80. In lieu of pressurized gas acting on the diaphragm 106, the rheological fluid in the chamber 110 of the valve 80 may be maintained under pressure by a spring-loaded piston. The torsion rods 24 of the left and right sections 16 and 18 may be connected with a thin rod extended through the housing 36 and the rotor 38 and piston 40 in it so that the two sections 16 and 18 are united to provide basic stiffness.